## **APPENDIX B** (Market Plan Selection Model)

Maximize $TotalRevenue - TotalSpillCost - TotalPaxCost - TotalStationCost - TotalLegCost$

Subject to

$$TotalRevenue = \sum_{p \in P} PlanRev(p)\ Plan(p)$$

$$TotalSpillCost = \sum_{l \in L} SpillCost(l)\ Spill(l)$$

$$TotalPaxCost = \sum_{l \in L} PaxCost(l)\left(Capacity(l) - Spoil(l)\right)$$

$$TotalStationCost = \sum_{s \in S} StationCost(s)\ Station(s)$$

$$TotalLegCost = \sum_{l \in L, q \in Q^{L}(l)} LegCost(l,q) Equipment(l,q)$$

$$\sum_{l \in L_{in}^{QST}(q,s,t)} Equipment(l,q) - \sum_{l \in L_{out}^{QST}(q,s,t)} Equipment(l,q) + GroundArc(q,s,prev(t)) - GroundArc(q,s,t)$$

$$= \mathrm{Balance}(\mathrm{q},\mathrm{s},\mathrm{t}), \forall(\mathrm{q},\mathrm{s},\mathrm{t}) \in \{\mathrm{Q} \times \mathrm{S} \times \mathrm{T}\}$$

$$\sum_{l \in \mathrm{Re}\, dEye(q)} Equipment(l,q) + \sum_{(s,t) \in S \times T^{S}(s): t = last(T^{S}(s))} GroundArc(q,s,t) \leq PlaneCount(q), \forall q \in Q$$

$$\sum_{l \in L^{Q}(q)} Equipment(l,q)\ BlockTime(l) \leq BlockTime(q), \forall q \in Q$$

$$\sum_{l \in L_{out}^{S}(s)} Leg(l) \geq MinOpp(s)\ Station(s), \forall s \in S$$

$$\sum_{l \in L_{out}^{S}(s)} Leg(l) \leq Station(s)\ M, \forall s \in S$$

$$\sum_{l \in L_{out}^{S}(s)} Leg(l) \leq MaxOpp(s), \forall s \in S$$

$$\sum_{l \in L^{SI}(svc)} Leg(l) \leq Service(svc)\ M, \forall svc \in S$$

$$\sum_{l \in L^{SI}(svc)} Leg(l) \geq MinSvcFreq(svc) Service(svc), \forall svc \in SI$$

$$\sum_{l \in L^{SI}(svc)} Leg(l) \leq MaxSvcFreq(svc), \forall svc \in SI$$

$$\sum_{q \in Q^{L}} Equipment(l,q)\ Size(q,l) = Capacity(l), \forall l \in L$$

$$\sum_{p \in P^{L}(l)} Demand(l,p)\ Plan(p) = Capacity(l) + Spill(l) - Spoil(l), \forall l \in L$$

$$\sum_{p \in P^{M}(m)} Plan(p) = Market(m), \forall m \in M$$

$$\sum_{p: l \in p} Plan(p) \leq Leg(l), \forall l \in L$$

$$\sum_{q \in Q^{L}(l)} Equipment(l,q) = Leg(l), \forall l \in L$$

$Market(m) \geq RequiredMarket(m), \forall m \in M$

$Service(si) \geq (1 - ThresholdSvcFreq(si)), \forall si \in SI$

$Station(s) \geq (1 - ThresholdOPP(s)), \forall s \in S$

$Leg(l) \geq RequiredLeg(l), \forall l \in L$

Variables

$TotalRevenue \geq 0$

$TotalSpillCost \geq 0$

$TotalPaxCost \geq 0$

$TotalStationCost \geq 0$

$TotalLegCost \geq 0$

$Plan(p) \in [0,1], \forall p \in P$

$Leg(l) \in \{0,1\}, \forall l \in L$

$GroundArc(q,s,t) \geq 0, \text{INTEGER}, \forall (q,s,t) \in Q \times S \times T$

$Equipment(l,q) \in \{0,1\}, \forall (l,q) \in L \times Q^{L}(l)$

$Spill(l) \geq 0, \forall l \in L$

$Spoil(l) \geq 0, \forall l \in L$

$Capacity(l) \geq 0, \forall l \in L$

$Service(svc) \in \{0,1\}, \forall svc \in SI$

$Market(m) \in \{0,1\}, \forall m \in M$

$Station(s) \in \{0,1\}, \forall s \in S$

| Parameter/Set | Source | Description |
|---|---|---|
| $P$ | Input from generate market plans | Set of all market plans |
| $S$ | Derived from overbuilt schedule. | Set of all stations. |
| $T^S(s)$ | Derived from overbuilt schedule. | Set of all points in time at which an arrival or departure can occur at station s. |
| $M$ | User input. | Set of all markets. |
| $P^M(m)$ | From generate market plans. | Set of all plans for market m. |
| $\text{Redeye}(q)$ | Identified when formulating the MIP | Set of all Equipment(l,q) variables that are associated with a flight over midnight. |
| L | From overbuilt schedule. | Set of all flight legs. |
| $Q^L(l)$ | From user input and input schedule. | Set of all equipment types that can be used on leg l. |
| $L_{in}^{QST}(q,s,t)$ | Identified when formulating the MIP. | Set of all flights that can use equipment q and that arrive at station s at time t. |
| $L_{out}^{QST}(q,s,t)$ | Identified when formulating the MIP. | Set of all flights that can use equipment q and that depart from station s at time t. |
| $L^Q(q)$ | Identified when formulating the MIP. | All flight legs that can use equipment q. |
| $L_{in}^S(s)$ | Identified when formulating the MIP. | All flight legs that arrive at station s. |
| $L_{out}^S(s)$ | Identified when formulating the MIP. | All flight legs that depart from station s. |
| $L^{SI}(svc)$ | Identified when formulating the MIP. | All flight legs that belong to service svc. |
| $P^L(l)$ | Identified when formulating the MIP. | All market plans that contain leg l. |
| $T^{QS}(q,s)$ | Identified when formulating the MIP. | All points in time at which a flight using equipment q can depart from or land at station s. |
| | | |
| PlanRev(p) | Input from APM | Revenue of market plan p. |
| SpillCost(l) | Input from APM | Estimated lost revenue of not accommodating (spilling) 1 customer on leg l. |
| PaxCost(l) | Input from APM | Cost of transporting one passenger on leg l. |
| StationCost(s) | Input from APM | Cost of operating station s. |
| LegCost(l,q) | Input from APM | Cost of operating equipment q on leg l. |
| Size(q,l) | Input from APM | Number of seats of equipment q on leg l. |
| Demand(l,p) | Input from APM | Demand for leg l associated with market plan p. |
| | | |
| BlockTime(l) | Input from user or input schedule | Time needed to fly leg l. |
| Balance(q,s,t) | Input from user or Feasibility model | Number of planes of type q on the ground at station s at time t |
| PlaneCount(q) | Input from user or Feasibility model | Number of available planes of type q. |
| BlockTime(q) | Input from user or Feasibility model | Total flying time available for type q. |
| MinOpp(s) | Input from user | Lower bound on origin point of presence at station s. |
| MaxOpp(s) | Input from user | Upper bound on origin point of presence at station s. |
| MinSvcFreq(si) | Input from user | Lower bound on service frequency for service si. |

| | | |
|---|---|---|
| MaxSvcFreq(si) | Input from user | Lower bound on service frequency for service si. |
| RequiredMarket(m) | Input from user | (0/1) Indicator: 1, if market m must be served. |
| ThresholdSvcFreq(si) | Input from user | (0/1) Indicator: 1, if service si can be dropped. |
| ThresholdOPP(s) | Input from user | (0/1) Indicator: 1, if station s can be closed. |
| RequiredLeg(l) | Input from user | (0/1) Indicator: 1, if leg l has to be flown. |

**Table 1 Parameters used in Market Plan Selection Model (Appendix B).**

| Variable | Type | Description |
|---|---|---|
| TotalRevenue | Continuous >= 0 | Total revenue of all selected market plans. |
| TotalSpillCost | Continuous >= 0 | Lost revenue of passengers that can not be accommodated due to capacity limitations. |
| TotalPaxCost | Continuous >= 0 | Total cost of transporting passengers. |
| TotalStationCost | Continuous >= 0 | Total cost of operating all chosen stations. |
| TotalLegCost | Continuous >= 0 | Total fixed operating cost of all selected flight legs. |
| Plan(p) | Continuous in (0,1) | Variable that indicates at what level plan p was selected. |
| Spill(l) | Integer >= 0 | Number of passengers that could not be accommodated on leg l. |
| Capacity(l) | Integer >= 0 | Capacity assigned to leg l. |
| Spoil(l) | Integer >= 0 | Number of seats on leg l that can not be sold. |
| Station(s) | Binary | A value of 1 indicates that station s is operated; a value of 0 indicates that station s is closed. |
| Equipment(l,q) | Binary | The variable is equal to 1 if equipment q is flown on leg l; 0 otherwise. |
| Leg(l) | Binary | Has value of 1, if leg l is operated; 0 otherwise. |
| GroundArc(q,s,t) | Integer >= 0 | Number of planes of type q that stay on the ground at station s at time t. |
| Service(svc) | Binary | Has value 1, if service svc is operated; 0 otherwise. |
| Market(m) | Binary | Has value 1, if market m is served; 0 otherwise. |

**Table 2 Variables used in Market Plan Selection Model (Appendix B).**

**Objective Function:**
Maximize total revenue minus operating and spill cost.

**Constraints:**

Total revenue is equal to the sum over all market plans of market plan revenue times market plan valuation.

Total spill cost is equal to the sum over all legs of the number of spilled passengers on a leg times the cost of spilling a passenger on the leg.

Total passenger cost is equal to the sum over all legs of the number of passengers accommodated on a leg times the cost of transporting a passenger on the leg.

Total station cost is equal to the sum of operating all open stations.

Total leg cost is equal to the sum of the equipment specific fixed costs of all legs that are flown.

Node Balance:
All planes that arrive at station s at time t or that are on the ground at station s at time t must right after time t either be on the ground right at station s or depart from station s.

Plane Count:
The number of planes of a given equipment type that are used in the schedule has to be less than or equal to the number of planes available for this equipment type.

Block Time:
The total flying time of all legs flown by a given equipment type must be less than or equal to the total flying time available for this equipment type.

Minimum Service Frequency:
If a service is operated then the service frequency must be greater than or equal to the user defined minimum service frequency for this service.

Maximum Service Frequency:
For each service, the frequency must be less than or equal to the user defined maximum service frequency for this service.

Minimum Origin Point of Presence:
If a station is operated then the number of flights departing from this station must be greater than or equal to the user defined minimum origin point of presence of this station.

Maximum Origin Point of Presence:
For each station, the number of flights departing from this station must be less than or equal to the user defined maximum origin point of presence of this station.

Station Opening:
A station must be operated if there is at least one flight arriving or departing from this station. The user specifies a set of stations that have to be operated.

Service Operation:
A service is considered as operated if at least one flight that belongs to the service is flown. The user specifies a set of services that have to be operated.

Leg Capacity:
The capacity of a flight leg is equal to the number of seats of the equipment assigned to the leg.

Demand:
The total demand for a flight leg is equal to the sum over all market plans that contain the leg of the market plan valuation times the demand associated with the leg in the market plan.

Spill and Spoil:
The demand for a flight leg is equal to capacity of the leg plus the number of spilled passengers minus the number of empty seats on the leg.

Market Plan selection:
The sum over all market plans that are selected at a fractional level for a given market is equal to one if service offered in the market and 0 otherwise. Service has to be offered in a market if the user requires it.

Equipment Assignment:
Exactly one equipment type is assigned to each flight that is flown. The user specifies a set of legs that have to be flown.